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HABITAT ASSOCIATIONS OF PIPING PLOVERS WINTERING IN THE UNITED STATES

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ABSTRACT.—During winter distribution surveys of Piping Plovers (*Charadrius melodus*) on the Atlantic Coast (1986–1987) and Gulf Coast (1987–1988) of the United States we examined factors affecting habitat use and documented associations with other species of shorebirds. Stepwise and discriminant analyses generated models that correctly classified Piping Plover presence 75% of the time for the Atlantic Coast and 65% of the time along the Gulf Coast. The presence of large inlets and passes and mudflats on the Atlantic Coast and beach width, number of small inlets, and beach area on the Gulf Coast appeared as important habitat features affecting presence of Piping Plovers. Both models suggest that habitat heterogeneity (including key feeding sites) may be more important than specific habitat features in affecting winter use of a site by Piping Plovers, however, models only explained 22–28% of the variability in habitat use. *Received 24 July 1989, accepted 10 Feb. 1990.*

The Piping Plover (*Charadrius melodus*) is endemic to North America where recent research has concentrated on breeding biology (Cairns 1982, Burger 1987, Haig and Oring 1988). Piping Plovers spend most of their annual cycle associated with wintering areas (Haig and Oring 1985), yet information on the wintering ecology of this species is sparse. This is significant because Baker and Baker (1973) speculated that winter may be an important portion of the annual cycle affecting mortality of migratory shorebirds. Most investigations of Piping Plovers during winter have occurred recently, and focus on population trends (unpubl. data, C. Raithel, Rhode Island Department of Environmental Management), distribution (Haig and Oring 1985, Nicholls and Baldassarre 1990) and ecology (Johnson and Baldassarre 1988). Few data exist relative to factors affecting winter habitat use.

During Atlantic and Gulf Coast distribution surveys, Haig and Oring (1985) speculated on potential winter habitat preference of Piping Plovers, whereas Johnson and Baldassarre (1988) noted that Piping Plovers wintering in Alabama used sandflats and mudflats versus beaches. However, neither study directly assessed winter habitat use over the broad winter range occupied by Piping Plovers. We studied the winter distribution of Piping Plovers along the Atlantic and Gulf coasts of the United States

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from 1986–1988 (Nicholls and Baldassarre 1990), during which time we quantified habitat characteristics associated with Piping Plovers during winter, and recorded associations with other wintering shorebirds.

STUDY AREA AND METHODS

The methodology associated with the winter distribution survey of Piping Plovers along the Atlantic Coast in 1986–1987 and along the Gulf Coast in 1987–1988 is detailed in Nicholls (1989) and Nicholls and Baldassarre (1990). Sites were surveyed for plovers by walking, or driving a truck or three-wheel all-terrain vehicle. Selected habitat features then were recorded within one-km sections using observed bird(s) as the center point of each section; a new section was sampled if the next bird observed was located outside of the first one-km section. Habitat data also were collected at regularly spaced intervals from sites without plovers. Specifically, all sites ≤three km were sampled as one section, sites 3.0 to 16 km long were sampled once (one-km section) every 1.6 km, sites 16 to 32 km were sampled every four km, and sites >32 km were sampled every eight km. We did not randomly sample non-plover sites because our primary objective was to locate wintering Piping Plovers, thus logistical constraints dictated that we sample sites in sequence. Also, although tidal activity can influence foraging activity of wintering Piping Plovers (Johnson and Baldassarre 1988), we did not control our sampling for tidal effects because we were only interested in presence or absence of Piping Plovers within a sample site rather than a specific behavior.

Habitat variables recorded within each one-km section (from water's edge to vegetation) were visual estimations of the percentages of beach, sandflat, mudflat, dredge spoil, water, and slope of the beach from the water's edge to vegetation (approximated with an Abney level). We also measured the beach width from the water's edge to vegetation, the number of tidepools, the number of ephemeral, small inlets (those not present at low tide), the number of permanent inlets or tidal creeks (medium-sized inlets), and the number of large inlets and passes. We collected substrate samples on the Gulf Coast from each sample section with Piping Plovers and at every fifth non-plover site. Surface and core samples were taken at depths of 0.5 and 5.0 cm, respectively, and analyzed for percent organic matter and percent sand, silt and clay (Soil Survey Staff 1967). For each Piping Plover sighted we also recorded the species and distance to its nearest neighbor as well as the specific microhabitat where each plover was observed (Table 1).

Discriminant function analysis (DFA) was used to develop models that best separated sites (occupied versus unoccupied) based on a subset of the habitat variables measured, and assuming equal prior probabilities (Pimental 1979). Stepwise DFA was conducted to evaluate the importance of individual variables and to eliminate unimportant variables from the model (SAS Institute 1988). Variables recorded as percents were arcsine transformed to meet statistical assumptions of normal distribution. Pearson product moment correlations were calculated between habitat variables and numbers of Piping Plovers. Multivariate analysis of variance (MANOVA) was conducted to test if group means of sites occupied by Piping Plovers differed from unoccupied sites (Pimental 1979).

We recognized two potential problems in the data relative to DFA, which were unequal group sizes, and violation of homoscedasticity. Specifically, the proportion of sites with plovers was smaller (0.25) than the proportion of sample sites without plovers (0.75). However, equal sample sizes created by taking a random sample of the non-plover sites did not improve the DFA results. Plover sites also represented the more homogeneous group (i.e., lower variance) than the non-plover sites, which created unequal dispersions (homogeneity tests were rejected, $P < 0.05$). These violations may affect significance tests associated with

TABLE 1
DESCRIPTIONS OF ATLANTIC AND GULF COAST MICROHABITATS USED BY WINTERING PIPING PLOVERS, DEC. 1986–MAR. 1988

Microhabitat	Description
Mudflat	Dark coloration, *Spartina* sp. nearest veg., soft to walk on, intertidal area generally on the bay side of barrier islands. Substrate characteristics: sand (79.6%), silt (2.2%), clay (2.3%), organic matter (OM) (0.9%); N = 22 sites.
Sandflat	Light brown coloration, dune grasses nearest veg., firm, intertidal area near large inlets/passes or tidepools/dune ponds. Substrate characteristics: sand (96.7%), silt (1.4%), clay (1.0%), OM (0.4%); N = 18 sites.
Sandy mudflat	Orange brown coloration, nearest veg. either dune grasses or *Spartina* sp., firm, intertidal area at overwash sites or inlets with an accreting spit. Substrate characteristics: sand (93.7%), silt (2.0%), clay (1.1%), OM (0.2%); N = 24 sites.
Upper beach	Light coloration, dune grasses nearest veg., soft, non-intertidal area, dry sand area above the berm crest on ocean side of barrier beach. Substrate characteristics: sand (98.6%), silt (1.4%), clay (2.6%), OM (0.6%); N = 6 sites.
Lower beach	Light coloration, dune grasses nearest veg., soft, intertidal area, wet sand or surf zone below the berm crest on ocean side of barrier beach. Substrate characteristics: sand (97.4%), silt (1.3%), clay (1.5%), OM (0.2%); N = 16 sites.
Dredge spoil	Dark coloration, no veg. usually present, soft and uneven surface, man-made areas along the intercoastal waterway. Substrate characteristics: sand (78.9%), silt (3.3%), clay (10.6%), OM (0.5%); N = 3 sites.

DFA (Williams 1981), thus our interpretation was based on the classification procedures and not on significance tests. In other words, we used DFA in a descriptive context rather than a predictive context because we were interested in identifying the variables important in group separation (i.e., plover versus non-plover sites). However, classification functions that predict presence reflect ability to separate groups based on habitat and thus can contribute biologically meaningful information (Green 1971, Rice et. al. 1983, Reinert 1984).

We used *t*-tests to compare habitat and substrate variables at sites occupied vs unoccupied by plovers, and sites with <five individuals (low density) vs >five individuals (high density). We assigned these high and low density groupings after comparing group size frequencies along both coasts (Nicholls 1989). Non-normal percentage data were transformed before all analyses (Zar 1974).

RESULTS

Habitat associations.—Stepwise DFA using the Atlantic Coast data selected the number of large inlets and passes, number of tidepools, % mudflat, beach width, and % sandflat as the major factors affecting plover presence or absence; the model explained 28% of the total variability in

TABLE 2

CORRECT CLASSIFICATION RESULTS OF PIPING PLOVER WINTER HABITAT USING DISCRIMINANT FUNCTION MODELS, DEC. 1986–MAR. 1988

	Percent correct predictions				
Class	Atlantic N = 466	Gulf N = 509	Both coasts N = 975	Atlantic test data[a] N = 233	Gulf test data[b] N = 255
Present	75 (50/67)[c]	65 (83/128)	59 (114/195)	55 (35/50)	63 (50/80)
Absent	84 (334/399)	78 (296/381)	77 (604/780)	70 (150/183)	74 (129/175)

[a] Results of cross-validation test of the Atlantic Coast data.
[b] Results of cross-validation test of the Gulf Coast data.
[c] Number of correct predictions/total number of observations.

habitat use. The Atlantic Coast model correctly classified Piping Plover presence 75% of the time and absence 84% of the time (Table 2). Structure coefficients, which indicate variables most closely associated with the derived function, were 0.686 for the number of large inlets and passes, 0.503 for % mudflat and 0.407 for the number of tidepools, 0.387 for beach width, and 0.341 for % sandflat. The Gulf Coast data then were used to cross-validate the Atlantic Coast function, which correctly identified plover sites 54% of the time and nonplover sites 70% of the time.

Stepwise DFA for the Gulf Coast selected beach width, % beach, % mudflat, and number of small inlets for the presence and absence criterion, and explained 22% of the total variability in habitat use. The Gulf Coast model correctly predicted presence 65% of the time and absence 78% of the time (Table 2). The structure coefficients identified beach width (−0.695), number of small inlets (−0.409), % mudflat (−0.222), and % beach (0.632), as most closely associated with the overall model. Cross-validation was performed by splitting the data and using half to develop a model and the other half to test it; results generally supported the first models. A final DFA was conducted on data combined from both coasts, and correctly predicted plover presence 59% of the time, and absence 77% of the time.

The MANOVA revealed that occupied versus unoccupied sites represented different habitats (Atlantic Coast: Wilk's lambda = 0.66, $F = 18.8$, $P < 0.01$; Gulf Coast: Wilk's lambda = 0.77, $F = 12.3$, $P < 0.01$). The habitat variables % sandflat, % mudflat, the number of medium-sized inlets, and the number of large inlets and passes were different between the Atlantic and Gulf Coast (t-test, $P < 0.05$, Table 2). Combining data from both coasts, the variables % dredge spoil, and number of medium-

TABLE 3
CHARACTERISTICS OF PIPING PLOVER WINTER HABITAT (MEAN ± SE) ON THE ATLANTIC AND GULF COASTS, DEC. 1986–MAR. 1988

	Atlantic Coast			Gulf Coast		
Variable	Present N = 67	Absent N = 399	*P*-value	Present N = 128	Absent N = 381	*P*-value
Beach width (m)	69.3 ± 7.0	45.2 ± 1.8	0.00	74.4 ± 4.7	42.4 ± 2.4	0.00
Slope (%)	0.6 ± 0.2	1.8 ± 0.1	0.00	1.2 ± 0.1	1.9 ± 0.1	0.00
% beach	42.3 ± 4.1	71.1 ± 1.4	0.00	46.1 ± 3.0	71.6 ± 1.8	0.00
% sandflat	31.7 ± 3.6	19.9 ± 1.0	0.00	18.9 ± 2.0	9.1 ± 0.5	0.00
% mudflat	12.9 ± 3.1	2.3 ± 0.6	0.00	21.5 ± 3.0	14.5 ± 1.6	0.02
% water	13.1 ± 1.8	4.5 ± 0.6	0.01	10.3 ± 1.1	4.6 ± 0.5	0.01
No. tidepools	0.7 ± 0.2	0.1 ± 0.0	0.00	0.3 ± 0.1	0.1 ± 0.0	0.01
No. small inlets	0.2 ± 0.0	0.2 ± 0.0	0.63	0.2 ± 0.0	0.1 ± 0.0	0.00
No. medium[a] sized inlets	0.1 ± 0.0	0.0 ± 0.0	0.16	0.1 ± 0.0	0.0 ± 0.0	0.11
No. large[a] inlets/passes	0.5 ± 0.1	0.1 ± 0.0	0.00	0.2 ± 0.0	0.2 ± 0.0	0.01

[a] Represents the percentage of present vs absent cases.

sized inlets did not differ (*t*-test, $P > 0.05$) between sites with or without birds. The variables % dredge spoil, number of small inlets, medium-sized inlets, and tidepools also did not differ ($P > 0.05$) between sites with high (>5) vs low (<5) plovers; all other variables were different ($P < 0.05$). Piping Plovers were observed on sandflats (27%), sandy mudflats (25%), mudflats (21%), upperbeach (14%), lowerbeach (7%), and dredge spoil (6%). The average substrate characteristics further defined these microhabitats (Table 3).

Surface and core substrate data were analyzed separately from habitat data because of the smaller sample size. No differences were found between substrate variables and presence or absence of plovers (*t*-test; $P > 0.05$). No differences ($P > 0.05$) were detected between sites with high and low numbers of plovers except for percent silt, which was greater in the surface sample at higher plover densities.

Interspecific associations and activity.—Piping Plovers almost always were found associated with other species of shorebirds or with other Piping Plovers (Piping Plovers were observed alone <1% of the time). We defined a Piping Plover as alone if no other shorebirds (including another Piping Plover) were within the one-km sample site formed by using the observed Piping Plover as the center point. Eighty-one percent of the Piping Plovers we observed were associated with more than five other shorebird species; only 4% were seen with one to two other species or were seen alone. The most frequent nearest neighbors were other Piping Plovers (57%), Sanderlings (*Calidris alba*) (11%), Least Sandpipers (*C. minutilla*) or Western Sandpipers (*C. mauri*) (11%), and Semipalmated Plovers (*Charadrius semipalmatus*) (9%). When the nearest neighbor was another Piping Plover, the distance was <1.6 m 50% of the time and 3.3–16.4 m 42% of the time, but <5% for distances >16.4 m, up to 1000 m (0.5 km). Overall, excluding other Piping Plovers as nearest neighbors, plovers were found 44% of the time near species that visually forage (i.e., plovers) and 56% of the time near species that are tactile foragers (i.e., sandpipers).

DISCUSSION

Habitat associations.—The Atlantic Coast test data and the low classification results for the DFA model when both coasts were combined suggest that different habitat variables may affect plover presence depending on the coast. Obvious physical differences exist between the coasts, which may affect shorebird habitat and justify creating separate models. For example, a stepwise DFA analysis using coast as the criterion variable identified percent sand, percent mud, percent beach, and beach width and slope as variables that significantly separated the two coasts.

The combination of habitat variables selected for DFA models on both coasts indicates that environmental heterogeneity may be an important factor differentiating sites that are occupied vs unoccupied by wintering Piping Plovers. For example, although classification results for the coastal models are reasonable, no variable alone was correlated highly with plover numbers or to the models (e.g., Pearson correlation coefficients between each variable and plover numbers were <0.2).

Along the Atlantic Coast the number of large inlets and passes may be an important habitat feature because 72% of sites with Piping Plovers were adjacent to these areas. Sandflats and sandy mudflats often were associated with large inlets and tidepools (also important in the model), and served as foraging areas for other species of wintering shorebirds. The low overall R^2 of 0.28 and a high degree of overlap in discriminant scores also (Nicholls 1989) may imply weak discriminating variables. Nevertheless, DFA did provide a preliminary overview of Piping Plover winter habitat. That the DFA correctly classified nonplover sites better than plover sites may be due to the paucity of birds seen on the Atlantic Coast (i.e., 222 birds; Nicholls 1989, Nicholls and Baldassarre 1990).

Plover sites vs non-plover sites on the Gulf Coast were characterized by greater beach width, greater % mudflats, lower % beach and more small inlets. Our general observations supported these data in that typical plover sites consisted of large areas of intertidal flats. For example, sites with narrow beaches (i.e., Santa Rosa Island, Florida; Padre Island National Seashore, Texas) often had little shorebird foraging habitat and few Piping Plovers, whereas barrier beaches with overwash areas (i.e., Honeymoon Island State Park, Florida and Chandeleur Islands, Louisiana) or with sections of mudflats (i.e., Rockefeller Refuge, Louisiana) attracted the largest concentrations (Nicholls 1989). The Gulf Coast function also had difficulty separating occupied versus unoccupied sites as reflected in the model R^2 of 0.22. However, the survey accounted for 1508 plovers and 176 wintering sites (Nicholls 1989), which should have contributed to greater group separation.

Misclassification of sites can be explained partially because it was assumed that sites with plovers had suitable habitat, whereas sites without plovers did not necessarily imply unsuitable habitat. Piping Plovers could be "missed" at some sites due to survey timing because Piping Plovers may make local movements within a general area depending on weather and tide conditions (Zivojnovich and Baldassarre 1987, Johnson and Baldassarre 1988). Shorebirds in general often move to alternate feeding habitats due to the cyclic tidal inundation of sand and mudflats (Evans 1976, Burger et al. 1977, Conners et al. 1981). Also, most plovers sighted on this survey were found foraging (72%), which indicates that we had difficulty locating roosting birds. Thus, this study is biased towards sites that had birds at the time of the survey. Additionally, "plover sites" may not be occupied because of the species' rarity. However, our large sample size on both coasts (Table 2) should have helped to ameliorate effects of misclassification.

Although it is difficult to determine habitat preference without exact detail on the availability of each microhabitat, Piping Plovers were observed foraging most frequently on sandflats and sandy mudflats. Further, most invertebrates identified in the fecal samples collected from Piping Plovers (Nicholls 1989, R. Heard pers. comm.) are associated with a wet sand, intertidal area, and sites with high plover densities also had more silt in the surface layer than sites with lower densities. Johnson and Baldassarre (1988) reported that foraging plovers predominantly used protected mudflats or exposed sandflats in Alabama, and Chapman (1984) found that feeding activities of Piping Plovers were confined to moist-sand substrates on Padre Island National Seashore, Texas. Burger et al. (1977) also noted that breeding Piping Plovers preferred the wet sand zone on inner and outer beaches in the Brigantine National Wildlife Refuge in New Jersey. Thus, because Piping Plovers spend a high amount of time foraging during winter (Johnson and Baldassarre 1988) we speculate that sandflats and sandy mudflats may attract the largest concentrations of Piping Plovers because of a preferred prey base, and/or because the substrate coloration provides protection from aerial predators due to chromatic matching (Graul 1973).

Interspecific associations. — Piping Plovers usually were found in mixed flocks of shorebirds, which may offer protection from predation (Goss-Custard 1970, Page and Whitacre 1975), or reflect availability of feeding sites (Myers et al. 1979). Piping Plovers appeared to stay together within these groups, however, as the nearest neighbor was another Piping Plover 57% of the time. The other small plovers (i.e., Snowy [*Charadrius alexandrinus*] and Semipalmated) were nearest neighbors only 3.8% and 9.0% of the time, respectively.

Johnson (1987) found that interspecific interactions often involved Snowy (29.4%) and Semipalmated plovers (23.5%). Baker and Baker (1973), however, suggested that individuals with similar foraging behavior should utilize different substrate patches. During this study, Snowy Plovers were observed primarily on the upper beach (37%), whereas Semipalmated Plovers were found mostly on mudflats (46%).

Overall, the habitat variables that may be important to wintering Piping Plovers include large inlets (or passes) and a high percentage of sandflat or mudflat, but the percentage of variability explained by the models is low. However, the identification of specific features responsible for a species' presence can be perplexing, especially if total community structure is the important component (Anderson 1981). Indeed, our data may indicate that distribution of Piping Plovers is correlated more with habitat heterogeneity versus specific habitat features. For example, sites with large concentrations of plovers (i.e., Little Dauphin Island in Mobile Bay, Alabama, and the Laguna Madre, Texas) consist of complex systems with several habitat types (i.e., roosting and feeding) in relatively close juxtaposition. We also believe that within these habitat complexes wintering Piping Plovers may depend on key feeding areas (i.e., intertidal flats) within which they may prefer specific microhabitats. We do not consider the information gained during this study as definitive, however, and do not recommend its use to determine critical wintering habitat. Nevertheless, these data do provide a foundation for future research on the winter ecology of this species.

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SCIENTIFIC SUMMIT ON THE RED-COCKADED WOODPECKER: SUMMARY REPORT

On March 28–30, 1990, the National Wildlife Federation convened a summit meeting of 24 experts on the biology and management of the endangered Red-cockaded Woodpecker (*Picoides borealis*). The Federation's objective in convening the summit was to establish points of consensus among scientists and managers on biological and management needs for protection and recovery of the species. The summit was mediated by a three-member team from the Southeast Negotiation Network. The summit report details areas of consensus, as well as short- and long-term needs of the species and a series of proposed management initiatives.

For a free copy of the report write: National Wildlife Federation, 1718 Peachtree St., Suite 592, Atlanta, Georgia 30309.